

REMARKS

Claims 1-10 are in the application for reconsideration, which is respectfully requested. Claim 1 has been amended to better describe the TFE polymer and the coagent.

The coagent is a lubricant (p. 6, l. 9) which when mixed with the TFE polymer fine particles form a paste mixture (p. 6, l. 7). The reason the TFE polymer fine particles are mixed with the lubricant to form the paste mixture (p. 6, l. 7) is to enable the resultant mixture to be extruded. This extrusion is carried out by forming a preform of the paste mixture, followed by extruding the preform through a much smaller orifice than the diameter of the preform (p. 6, l. 33 to p. 7, l. 2). On p. 8, l. 33-37, it is disclosed that the preform has a diameter of 30.9 mm and the orifice has a diameter of 3.17 mm. The preform of the paste mixture is simply rammed through the small diameter orifice. The paste consistency of the paste mixture enables the TFE polymer fine particles to be extruded in this way.

The TFE polymer fine particles are also further described in claim 1 as being fibrillatable, the extent of which is defined by the minimum extrusion pressure of not less than 220 kg/cm² already recited in the claim. This extrusion, which can be called paste extrusion, subjects the TFE polymer fine particles to high shear force which fibrillates the TFE polymer fine particles (p. 4, l. 20-22 and p. 7, l. 16-19). This disclosure of the fibrillation of the TFE polymer fine particles indicates that these particles are fibrillatable. This fibrillatability arises from the structure of the TFE polymer being used (p. 4, l. 32-35). The importance of fibrillation of the TFE polymer fine particles is that this enhances the binding strength with respect to the electrode material (p. 4, l. 32-35).

A further explanation of the paste extrusion involving the use of the lubricant coagent may be of interest. Paste extrusion is a fabrication technique for non-melt fabricable polytetrafluoroethylene, i.e. PTFE that does not flow in the molten condition whereby such polymer cannot be melt-fabricated. The non-melt fabricable condition for the PTFE arises from the extremely high molecular weight of the polymer. This high molecular weight is indirectly measured by standard specific gravity (SSG) as disclosed on p. 4, l. 23-26. The application of SSG to the TFE polymer recited in claim 1, which includes PTFE, indicates that it, like PTFE, is non-melt-fabricable. As disclosed in the present specification, the amount of comonomer is very small (p. 5, l. 24) such that SSG not being more than about 2.20 assures that the TFE polymer is in the family of non-melt fabricables along with PTFE (p. 4, l. 28-31). Comonomer-modified PTFE wherein the non-melt-fabricable character of the PTFE is retained is disclosed for example in U.S. Patent 3,142,665 (copy attached). Paste extrusion is carried out at a temperature much lower than the melting temperature of the TFE polymer, which is close to the melting temperature of PTFE (343°C - first melt and 327°C - subsequent melts). The temperature of this paste extrusion is limited by the temperature at which the lubricant coagent boils away, e.g. dry point not exceeding 145°C as disclosed on p. 6, l. 13-

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14). Dry point is the temperature at which the last drop of liquid evaporates from the bottom of a flask (see McGraw-Hill Dictionary of Scientific and Technical Terms, McGraw-Hill Book Company (1969), p. 447 (copy attached)). Typically, the paste extrusion is carried out at room temperature.

Claim 2 and the specification have been corrected to name the monomer intended in accordance with the disclosure on p. 5, l. 15 and p. 8, l. 15. Literature can be supplied if the Examiner desires, showing that the acronym PFBE means perfluorobutyl ethylene.

Claim 6 has been amended similar to claim 1 to recite the TFE polymer fine particles are fibrillatable and that the coagent is a lubricant, the same as claim 1. Claim 6 has been further amended to recite the fibrillation effect of the mixing. The application of high shear force to the polymer causes the polymer to fibrillate (p. 4, l. 20-23). The mixing has to be very intense, together with the particles being very small and low SSG, to supply the high shear force necessary for fibrillation. High shear force is implied in the mixing recited in claim 6 which brings about the fibrillation result to enhance the binding strength of the binder to the electrode material (p. 4, l. 33-35). One embodiment for the application of this high shear force in the mortar/pestle mixing disclosed on p. 9, l. 23-27, which enables just 0.3 wt% TFE polymer fine particles to bind the electrode material together. Paste extrusion, i.e. ramming a large diameter preform through a small orifice, is another high shear process that qualifies the TFE polymer fine particles by particle size and SSG to be the fibrillating binder.

Claim 7 has been amended in the same manner as claim 2.

New claim 10 claims the product of the process of claim 6

With respect to the objection to the specification and claim objections, the foregoing discussed amendments to the specification and claims 2 and 7 are believed to satisfactorily address these objections.

With respect to the rejection of claims 1-8 as being obvious over Tamura et al. (Tamura) in view of Findlay et al. (Findlay), there are many differences between the claims to the present invention and Tamura, which are not satisfied by Findlay, as follows:

1. Tamura does not disclose its PTFE is the type that fibrillates when subjected to high shear force. There are two types of non-melt-fabricable PTFE, the granular type and the fine powder type as disclosed in pp. 400 and 401 in Ullmann's Encyclopedia of Industrial Chemistry, published by VCH Verlagsgesellschaft mbH (1988) (pp. 400 and 401 attached), it is only the fine powder type that is fibrillatable (p. 401).
2. Tamura does not disclose a mixing process that fibrillates the polymer to effect the binding of the electrode material together (claim 6). In Tamura, the electrode materials including the PTFE powder are merely packed together (col. 4, l. 19-23). The significance of fibrillation doing the binding is apparent from the greater loading of the PTFE powder in the electrode composition in Tamura than needed according to

the present invention. Tamura discloses a PTFE loading of 4 to 10 wt% (col. 3, l. 52-57), and 7 wt%, representing the preferred embodiment, is used in the Examples. In contrast, the TFE polymer loading used in the present invention can be less than 1 wt%. Only 0.3 wt% is used in the Examples (see p. 9, l. 23-24). This improved result is embodied in the claims 1 and 6 both by the fibrillatability of the TFE polymer fine particles and by the high extrusion pressure caused by such fine, low SSG polymer particles, and additionally in claim 6, by the mixing to fibrillate step. This improved result is important because the polymer loading should be as little as possible, while providing the binding function, because the polymer is a dielectric in an electrode material that requires high electrical conductivity.

3. While Tamura does disclose in Example 3 the use of 0.01 μm PTFE particles, Tamura does not find these small particles any better than the 1 and 3 μm PTFE particles. The discharge curves (Fig. 4) for compositions with the three particle sizes are grouped together, with the 1 μm size (curve L) being better than the 0.01 μm size (curve K), which in turn is only slightly better than the 3 μm size (curve M). The PTFE particle size of up to 3 μm is an enormous particle size range as compared to the maximum TFE polymer particle size of up to about 0.2 μm . The particle size range of the present invention (claims 1 and 6) constitute less than 7% of the Tamura range. Tamura does not suggest using the 0.01 μm size PTFE particles in Applicant's different context of the TFE polymer being fibrillatable (claim 1) and being fibrillated (claim 6) to bind the electrode materials together.
4. The small particle size of no more than about 0.2 μm recited in claims 1 and 6 has criticality that is missing from Tamura. The small TFE polymer particles are required in the present invention to obtain the high paste extrusion pressure of not less than about 220 kg/cm^2 recited in claims 1 and 6, which characterizes the extent of fibrillatability of the TFE polymer. Comparative Example 3 in Table 1 shows that even when the SSG of the polymer is less than 2.20, the 0.27 μm size TFE polymer particles produce an extrusion pressure of only 216 kg/cm^2 , which is less than the claim 1 and 6 minimum.
5. The small particle size for the TFE polymer particles is important in the present invention in combination with SSG no more than about 2.20 as recited in claims 1 and 6. As shown in Table 1, for comparative Examples 1 and 2, wherein both SSG and particle size are greater than the values recited in claims 1 and 6, the extrusion pressure is less than $\frac{1}{2}$ of the paste extrusion pressure obtainable with both low SSG and small particle size TFE polymer fine particles and much less than the corresponding values recited in claims 1 and 6.
6. To summarize the foregoing differences from Tamura, Tamura does not disclose (i) fibrillatable PTFE powder, (ii) fibrillating the polymer in the formation of the

electrode, (iii) the benefit of fibrillation, namely smaller loading of polymer binder, and (iv) the criticality of polymer particle size both per se and in combination with low SSG to provide effective fibrillation.

These are fundamental differences from Tamura. Of course there is the difference recognized in the Office Action that Tamura does not disclose the coagent recited in claims 1 and 6.

Findlay is cited as disclosing Applicant's coagent. While the term coagent is found both in Findlay and Applicant's claims 1 and 6, the function is quite different. Findlay does not refer to his coagent as a lubricant as now recited in claims 1 and 6, but instead refers to his coagent as follows:

"unsaturated coagent....Curing recipes of this type are well known in the art, and are described in more detail in U.S. Patent 4,035,565. (col. 4, l. 37-41)

This patent is attached hereto and better defines coagent as follows:

"Another material which is usually blended with the composition before it is made into end products is a coagent composed of a polyunsaturated compound which is capable of cooperating with said peroxide [curing agent] to provide a useful cure." (col. 6, l. 19-23)

Thus, the coagent of Findlay is not a lubricant. Findlay extrudes a fluoroelastomer composition, which as shown in Example 4 is capable of extrusion without an additive. Findlay provides no information for combining with Tamura to use a fibrillatable TFE polymer, and to fibrillate it for more effective binding together of electrode material, or to use only very small polymer particles per se or in combination with low SSG polymer, which together produce a paste extrusion pressure of at least 220 kg/cm² necessary for effective fibrillation.

The rejection considers that Findlay fluoroelastomer blend of a non-crosslinked fluoroelastomer and a partially crosslinked fluoroelastomer is fundamentally the same as the PTFE of Tamura, when in fact fluoroelastomer and PTFE are quite different. PTFE has no melt flow and is not elastomeric, while fluoroelastomer is an amorphous polymer not having any melting point, but having a low glass transition temperature, such that the fluoroelastomer has high flow even at low temperatures, which why the fluoroelastomer must be crosslinked for utility. The ability to extrude fluoroelastomer prior to complete curing has nothing to do with TFE polymer fine particles having the ability to bind electrode material together by fibrillation. Most significant is the fact that the use of the coagent in Findlay's fluoroelastomer blend does not suggest either utility for this coagent in Tamura or that the coagent is a lubricant as now recited in Applicant's claims 1 and 6.

The rejection considers that some of Tamura's PTFE have may have the claimed SSG of 2.12 to 2.19. This treatment of PTFE SSG misses the point (a) that no SSG is disclosed in Tamura and no importance for any particular SSG is found in Tamura, and (b) that SSG

together with small particle size is important for effective fibrillation, as characterized by minimum extrusion pressure, none of which is disclosed in either Tamura or Findlay. The basing of any rejection on what SSG the Tamura PTFE "may have" is in contravention of the authority of In re Oelrich, 212 USPQ 323,326 (CCPA 1981), which requires that to establish inherency, the descriptive matter missing from the reference must necessarily be present in the reference and cannot be established by probabilities or possibilities.

The rejection refers to the Tamura PTFE particle sizes up to 30 μm with relation to the particle size range of claims 3 and 8. Presumably the rejection means PTFE particle sizes up to 3 μm with relation to the claimed particle sizes. This view of particle size in isolation from PTFE type, fibrillation of the PTFE, maximum small particle size and low SSG to produce a large minimum extrusion pressure, all missing from Tamura, is not a reasonable ground for rejection of claims 3 and 8.

The rejection mentions die swell in Findlay and asserts that die swell increases with increasing pressure as though relevant to the paste extrusion minimum pressure characterization recited in claims 1 and 6. It is believed that the Examiner recognizes that in the extrudate of Findlay does not consist of particles of the fluoroelastomer. At least some of the fluoroelastomer must flow together to form continuous phase in order for the extrudate to have integrity. The presence of die swell is an indication of that integrity, that the extrudate has a continuous phase that can expand upon exiting the die. In contrast, the paste extrusion characterization of the TFE polymer fine particles produces the polymer entirely in fibrillated particle form. The die swell of Findlay provides no guidance to using fibrillatable TFE polymer fine particles, low SSG, small TFE polymer particle size, to produce a high minimum paste extrusion pressure required to obtain effective fibrillation of the TFE polymer fine particles.

In view of the foregoing, allowance of the above-referenced application is respectfully requested.

Applicant has herein presented amendments to claims and argument for patentability that provide a reasonable basis for allowance of this application. If the Examiner has a different idea for amendment for allowability, proposal of this idea would be appreciated, as a better course of action that just unnecessarily prolonging the patent procurement proceedings.

A petition of three month extension of time and payment of the required fee is filed herewith.

Respectfully submitted,

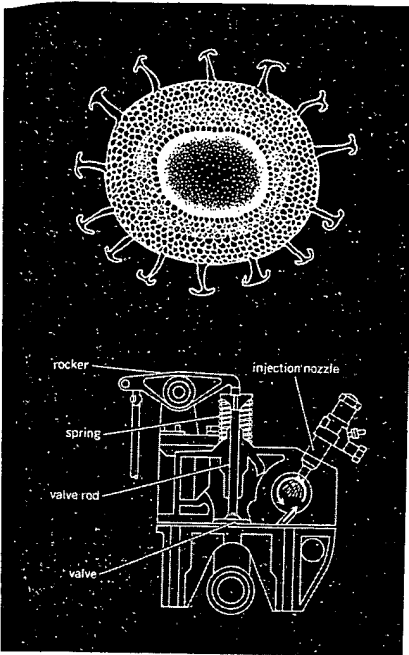
A handwritten signature in cursive script, appearing to read "Edwin Tocker".

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In addition, material has been drawn from the following references: R. E. Huschke, *Glossary of Meteorology*, American Meteorological Society, 1959; *U.S. Air Force Glossary of Standardized Terms*, AF Manual 11-1, vol. 1, 1972; *Communications-Electronics Terminology*, AF Manual 11-1, vol. 3, 1970; W. H. Allen, ed., *Dictionary of Technical Terms for Aerospace Use*, 1st ed., National Aeronautics and Space Administration, 1965; J. M. Gilliland, *Solar-Terrestrial Physics: A Glossary of Terms and Abbreviations*, Royal Aircraft Establishment Technical Report 67158, 1967; *Glossary of Air Traffic Control Terms*, Federal Aviation Agency; *A Glossary of Range Terminology, White Sands Missile Range, New Mexico*, National Bureau of Standards, AD 467-424; *A DOD Glossary of Mapping, Charting and Geodetic Terms*, 1st ed., Department of Defense, 1967; P. W. Thrush, comp. and ed., *A Dictionary of Mining, Mineral, and Related Terms*, Bureau of Mines, 1968; *Nuclear Terms: A Glossary*, 2d ed., Atomic Energy Commission; F. Casey, ed., *Compilation of Terms in Information Sciences Technology*, Federal Council for Science and Technology, 1970; *Glossary of Stinfo Terminology*, Office of Aerospace Research, U.S. Air Force, 1963; *Naval Dictionary of Electronic, Technical, and Imperative Terms*, Bureau of Naval Personnel, 1962; *ADP Glossary*, Department of the Navy, NAVSO P-3097.

McGRAW-HILL DICTIONARY OF SCIENTIFIC AND TECHNICAL TERMS

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dry drilling [MIN ENG] Drilling in which chippings and cuttings are lifted out of a borehole by a current of air or gas.

dry electrolytic capacitor [ELEC] An electrolytic capacitor in which the electrolyte is a paste rather than a liquid; the dielectric is a thin film of gas formed on one of the plates by chemical action.

dry flashover voltage [ELECTR] Voltage at which the air surrounding a clean dry insulator or shell completely breaks down between electrodes.

dry fog [METEOROL] A fog that does not moisten exposed surfaces.

dry freeze [HYD] The freezing of the soil and terrestrial objects caused by a reduction of temperature when the adjacent air does not contain sufficient moisture for the formation of hoarfrost on exposed surfaces.

dry friction [MECH] Resistance between two dry solid surfaces, that is, surfaces free from contaminating films or fluids.

dry gangrene [MED] Local death of a part caused by arterial obstruction without associated venous obstruction or infection.

dry gas [MATER] A gas that does not contain fractions which may easily condense under normal atmospheric conditions, for example, natural gas with methane and ethane.

dry grinding [ENG] Reducing particle sizes without a liquid medium.

dry haze [METEOROL] Fine dust or salt particles in the air, too small to be individually apparent but in sufficient number to reduce horizontal visibility, and to give the atmosphere a characteristic hazy appearance.

dry hole [ENG] A hole driven without the use of water.

[PETRO ENG] A well in which no oil or gas is found.

dry ice [INORG CHEM] A trade name for carbon dioxide in the solid form, usually made in blocks to be used as a coolant; changes directly to a gas at -78.5°C as heat is absorbed.

drying [CHEM] 1. An operation in which a liquid, usually water, is removed from a wet solid in equipment termed a dryer. 2. A process of oxidation whereby a liquid such as linseed oil changes into a solid film.

drying agent [CHEM] Soluble or insoluble chemical substance that has such a great affinity for water that it will abstract water from a great many fluid materials; soluble chemicals are calcium chloride and glycerol, and insoluble chemicals are bauxite and silica gel. Also known as desiccant.

drying oil [MATER] Relatively highly unsaturated oil, such as cottonseed, soybean, and linseed oil; that is easily oxidized and polymerized to form a hard, dry film on exposure to air; used in paints and varnish.

drying oven [ENG] A closed chamber for drying an object by heating at relatively low temperatures.

Dryinidae [INV ZOO] A family of hymenopteran insects in the superfamily Bethyloidea.

dry kiln [ENG] A heated room or chamber used to dry and season cut lumber.

dry measure [MECH] A measure of volume for commodities that are dry.

dry mill [FOOD ENG] A machine for processing corn consisting of a horizontal, revolving conical drum covered with metal projections, in a housing also studded with metal projections and having small perforations through which pass fine particles of hull and germ. [MECH ENG] Grinding device used to powder or pulverize solid materials without an associated liquid.

dry mining [MIN ENG] Mining operation in which there is no moisture in the ventilating air.

dry mounting [GRAPHICS] A method for mounting photographs and other paper materials on cardboard without paste or rubber cement; a light, thin tissue (mounting tissue) is placed over the photograph and heat is applied with slight pressure so that the photo will adhere to the cardboard.

dry offset See letter set.

Dryomyzidae [INV ZOO] A family of myodarian cyclorrhaphous dipteran insects in the subsection Acalypteratae.

Dryopidae [INV ZOO] The long-toed water beetles, a family of coleopteran insects in the superfamily Dryopoidea.

Dryopoidea [INV ZOO] A superfamily of coleopteran insects

in the suborder Polyphaga, including the nonpredatory aquatic beetles.

dry ore [MIN ENG] An ore of gold or silver which requires added lead and fluxes for treatment.

dry permafrost [GEOL] A loose and crumbly permafrost which contains little or no ice.

dry pint See pint.

dry-pipe system [ENG] A sprinkler system that admits water only when the air it normally contains has been vented; used for systems subjected to freezing temperatures.

dry-pit pump [MECH ENG] A pump operated with the liquid conducted to and from the unit by piping.

dry placer [MIN ENG] A gold-bearing alluvial deposit found in arid regions; it cannot be mined due to lack of water.

dry plate [GRAPHICS] A photographic plate that has a sensitized coating of an emulsion of silver halide in gelatin which is dried before exposure to light in the photographic process.

dry-plate rectifier See metallic rectifier.

dry point [ANALY CHEM] The temperature at which the last drop of liquid evaporates from the bottom of the flask.

drypoint etching [GRAPHICS] Etching in which a sharp tool (an etching needle) scratches through only the etching ground that is placed on the surface of the copper plate; the plate is then placed in an acid bath, and the chemical action produces a line deep enough to hold ink.

dry pressing [ENG] Molding clayware by compressing moist clay powder in metal dies.

dry pt See pint.

dry-reed relay [ELEC] Reed-type relay which does not use mercury at the relay contacts.

dry reed switch [ELEC] A switch having contacts mounted on magnetic reeds in a vacuum enclosure, designed for reliable operation in dry circuits.

dry-relief offset [GRAPHICS] Referring to plates made for use on offset-lithographic presses, but printed without the use of dampeners and water; the plates are made photomechanically, and nonprinting areas are etched from 0.008 to 0.015 inch (0.2 to 0.4 millimeter) below the surface. Also known as high etch.

dry rot [MICROBIO] A rapid decay of seasoned timber caused by certain fungi which cause the wood to be reduced to a dry, friable texture. [PL PATH] Any of various rot diseases of plants characterized by drying of affected tissues.

dry run [ENG] Any practice test or session. [ORD] Any simulated firing practice, particularly a dive-bombing approach made without the release of a bomb.

dry sample [MIN ENG] A sample of ore obtained by dry drilling.

dry sand mold [MET] A mold made of greensand and then dried in an oven to increase its strength.

Drysdale ac polar potentiometer [ENG] A potentiometer for measuring alternating-current voltages in which the voltage is applied across a slide-wire supplied with current by a phase-shifting transformer; this current is measured by an ammeter and brought into phase with the unknown voltage by adjustment of the transformer rotor, and the unknown voltage is measured by observation of the slide-wire setting for a null indication of a vibration galvanometer.

dry season [CLIMATOL] In certain types of climate, an annually recurring period of one or more months during which precipitation is at a minimum for the region.

dry sieving [ENG] Particle-size distribution analysis of powdered solids; the sample is placed on the top sieve screen of a nest (stack), with mesh openings decreasing in size from the top to the bottom of the nest.

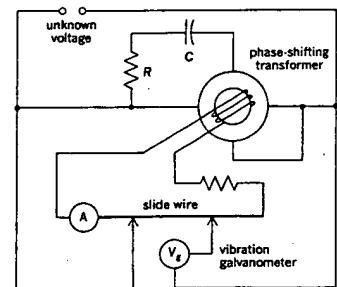
dry socket [MED] Inflammation of the dental alveolus, especially the inflamed condition following the removal of a tooth. Also known as alveolitis.

dry spell [CLIMATOL] A period of abnormally dry weather, generally reserved for a less extensive, and therefore less severe, condition than a drought; in the United States, describes a period lasting not less than 2 weeks, during which no measurable precipitation was recorded.

dry spot [ENG] An open area of an incomplete surface film on laminated plastic.

drystone [GEOL] A stalagmite or stalactite formed by dropping water.

DRYSDALE AC
POLAR POTENTIOMETER



Drysdale ac potentiometer circuit.
(From I. F. Kinard, *Applied Electrical Measurements*, Wiley, 1956)

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Table 4. Electrical properties of PTFE resins

Property	Granular	Fine powder	ASTM
Dielectric constant, 60 Hz to 2 GHz	2.1	2.1	D 150
Dissipation factor, 60 Hz to 2 GHz	0.0003		D 150
Volume resistivity, $\Omega \cdot \text{cm}$	$> 10^{18}$	$> 10^{18}$	D 257
Surface resistivity, Ω/m^2	$> 10^{16}$		D 257
Surface arc resistance, s	> 300	> 300	D 495
Dielectric strength, 2-mm thickness, kV/mm	23.60	23.60	D 149

strength and corona resistance of fabricated parts. Voids must be minimized to achieve optimum electrical insulation.

Chemical Resistance. Polytetrafluoroethylene is resistant to attack by most chemicals, including aqua regia, hot fuming nitric acid, hot caustic, gaseous chlorine, chlorosulfonic acid, organic esters, ketones, and alcohols. The only materials known to attack PTFE are molten alkali metals, chlorine trifluoride, and gaseous fluorine at elevated temperature and pressure. Some highly fluorinated oils can swell or dissolve PTFE near its melting point. A list of chemicals that are compatible with PTFE is available [27].

Flame Resistance. Polytetrafluoroethylene is one of the most flame-resistant polymers known and does not support combustion in air. It has an extremely high limiting oxygen index (LOI) of 96%, i.e., it burns only in almost pure (96 vol%) oxygen.

Weatherability. The weatherability of PTFE is remarkable; it is completely unaffected by all types of weather from dry desert heat to humid jungle conditions. Test films showed no change after 20–30 years of continuous exposure in Florida.

Radiation Resistance. On exposure to a high-energy electron beam or gamma radiation, PTFE undergoes degradation rather than cross-linkage. In the absence of oxygen, stable radicals are produced which slow down the rate of degradation. However, in the presence of air, the radicals react with oxygen which accelerates scission and degradation. On exposure to 10^4 Gy (1 Mrad) of radiation in air, PTFE loses 50% of

its original tensile strength. Irradiation also affects its electrical properties: resistivity decreases, whereas the dielectric constant and dissipation factor increase.

Thermal Stability. In both air and nitrogen, PTFE has an extremely high thermal stability. Rates of decomposition are not measurable below ca. 440 °C, decomposition rates are high at 540 °C. In vacuum pyrolysis of thin films, first-order thermal decomposition occurs, the TFE monomer being the main product [28]; the activation energy is 347.4 kJ/mol. The melt viscosity decreases during pyrolysis which probably involves random chain cleavage followed by depolymerization (short kinetic chain length) and termination by disproportionation.

2.2.3. Processing

Granular Resins. Moldings are produced from granular resins in three steps: First, the dry powder is placed in a mold and compressed at moderate temperature to produce a preform that is strong enough for handling without breaking. The preform is then placed in an oven at 380 °C to allow the particles to coalesce. This operation is called sintering. The final step is controlled cooling to produce the desired crystallinity. Granular resins are available in a number of forms that are optimized for different types of molding. High-flow resins are used in small and automatic moldings. Finely divided resins are preferred for large billet moldings to which they impart superior properties. Presintered resins are easier to handle and are preferred in ram extrusion applications. Most PTFE manufacturers give detailed descriptions of molding equipment and procedures [29].

Automatically molded articles require no further finishing after molding. However, large billets and rods are subsequently skived or machined. Film and sheet are produced by skiving a billet on a lathe. Precision parts can be machined from ram-extruded rods. Another method, called coining, is used for articles that are too complicated to make by machining. In this operation, a sintered molding is heated to the melting point, quickly pressed into a mold cavity, and held under pressure until it resolidifies. Coined moldings are limited in their upper service temperature. After long periods at high temperature, they return to their original precoining shape.

Fine Powder Resins. The paste-extrusion process for fine powder resins represented an important advance in PTFE processing. It permits the manufacture of continuous PTFE tubing and continuous PTFE coatings on wires.

In paste extrusion, 15–25 wt % of lubricant (a petroleum fraction, usually kerosene) is mixed with the fine powder resin. The wetted powder is then gently shaped into a preform at low pressure. (Fine powder resins are extremely sensitive to shear; great care must be taken to avoid shearing the powder before extrusion, otherwise processibility may be lost.) The preform is forced through a die mounted in the extruder. The high shear exerted at the die fibrillates the powder and confers “green strength” to the extrudate. The lubricant is then evaporated and the extrudate is sintered at 380 °C to coalesce the elongated particles. Drying and sintering are performed consecutively by passing the extrudate through a multistage oven located directly after the extruder. Residence time in the oven can vary from a few seconds for thin-walled wire insulation to a few minutes for large-diameter tubing. Extrusion pressure depends on the reduction ratio, the extrusion rate, the lubricant content, and the extruder characteristics.

Paste extrusion is also used to produce unsintered tape. Lubricant mixing and extrusion are the same as above. The product is extruded into rods, which are calendered on hot rolls to the desired dimensions.

Different fine powder resins have been developed for different applications. Powders that are suitable for high reduction-ratio applications, such as wire coatings, are not usually suitable for medium reduction-ratio applications such as tubing. (The reduction ratio is the ratio of the die diameter to the product diameter.) Thread sealant tapes are generally produced with other special grades. New types of fine powder resins are constantly being developed, leading to both improved and new applications and processing techniques [30]–[32].

Dispersion Resins. In general, PTFE dispersions are concentrated to 50–60 % solids and stabilized by a nonionic surfactant. The dispersions are applied to various substrates by spraying, flow-coating, dipping, coagulating, or electrodepositing. Films can be made by casting the aqueous dispersion on a supporting surface, drying, baking, and cooling. If the film is too thick, cracks develop; the maximum film thick-

ness per application is ca. 40 μm . Thicker coatings are made by casting and baking a series of layers.

An important application of PTFE dispersions is cloth impregnation. The woven cloth (e.g., fiber glass) is usually dipped into the dispersion and dried and sintered as in film formation. In some cases, the fiber is coated with the PTFE dispersion before weaving. Dispersions are also used in the production of PTFE fibers [33]. The dispersion is mixed with a matrix-forming medium such as viscose and spun into fibers through a spinneret and coagulating bath. The fibers are heated to remove the matrix polymer, sintered, and drawn for spinning.

2.2.4. Uses

About half of the PTFE resin that is produced is used for electrical purposes [34]. A major application is PTFE-insulated hookup wire used in military and aerospace electronic equipment. Polytetrafluoroethylene is also used in coaxial cables wrapped with PTFE tape, as insulation for airframe and computer wires, as well as in electrical components and “spaghetti” tubing.

Other important uses of PTFE resin are found in fluid-conveying systems, where it is used for gaskets, molded packings and seals, piston rings, bellows, overbraided hose, and lined pipe. Laboratory apparatus is also made of PTFE.

In static and dynamic load supports, large quantities of PTFE are used for bearings, ball- and roller-bearing components, and sliding bearing pads. The most common use known is as a release coating; PTFE-coated cookware utilizes a large amount of resin each year. Sheet and pressure-sensitive tape also serve for release applications.

Architectural fabrics are made by coating heavy-duty glass fabric with PTFE dispersions. These materials have outstanding weatherability and are resistant to chemicals, microorganisms, and fire. They have been used to enclose football stadiums and shopping centers.

Fibers and filaments are used in the production of PTFE filter cloth. Highly porous fabrics (e.g., Gore-Tex) are prepared by a process based on the fibrillation of high molecular mass PTFE. These fabrics have a high permeability for water vapor, but none for liquid water. They are widely used in outdoor wear and camping accessories.